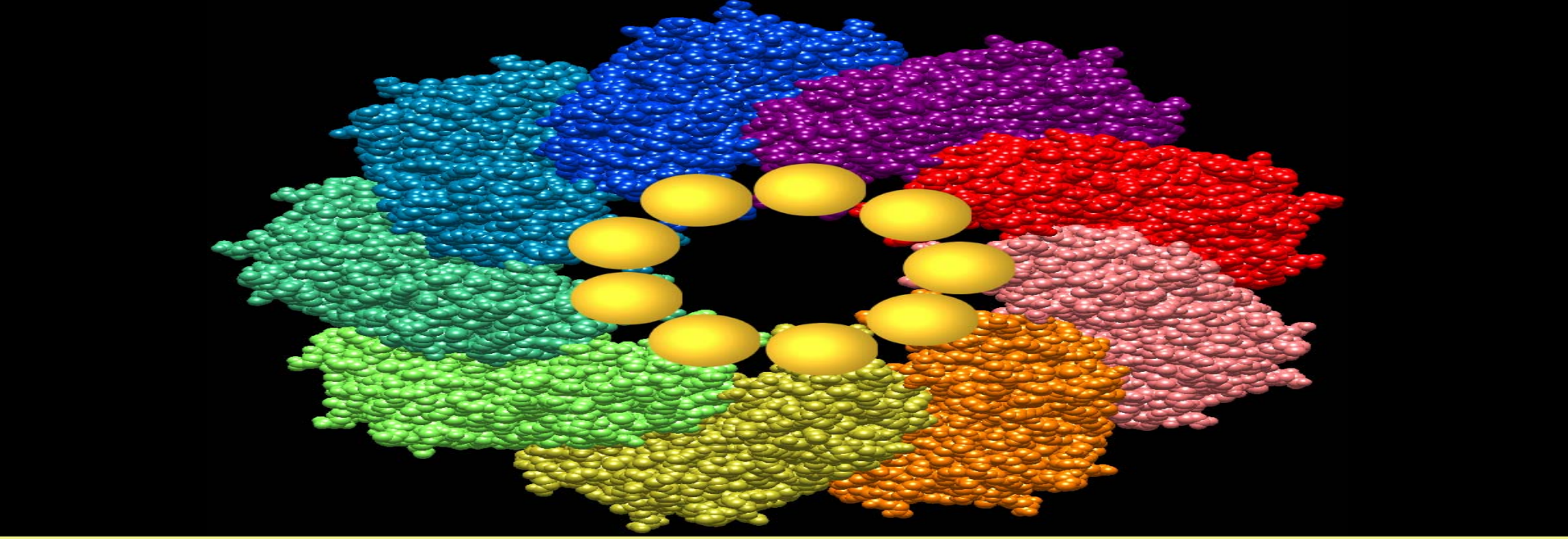


# *Global Risk Governance of Nanotechnology*

**M.C. Roco**

National Science Foundation,
National Nanotechnology Initiative, and
International Risk Governance Council

Taipei, August 31, 2007

# *Topics*

- What is special about nanotechnology?
- Possibilities for global governance
- Risk governance of nanotechnology
- Nano environmental research at NSF / NNI

Benchmark with experts in over 20 countries

"Nanostructure Science and Technology"

*Book Springer, 1999*

## Nanotechnology

is the **control and restructuring of matter** at dimensions of roughly 1 to 100 nanometers (from about 1 atom to about 100 molecular diameters),

where new phenomena

enable new applications

# WHAT IS SPECIAL ABOUT NANOTECHNOLOGY ?

- Reaches at the basic level of organization of atoms & molecules, where the fundamental properties/functions of manmade and living systems are defined and can be changed
- Broad technology platform
  - for industry, biomedicine, environment

*Consequences*

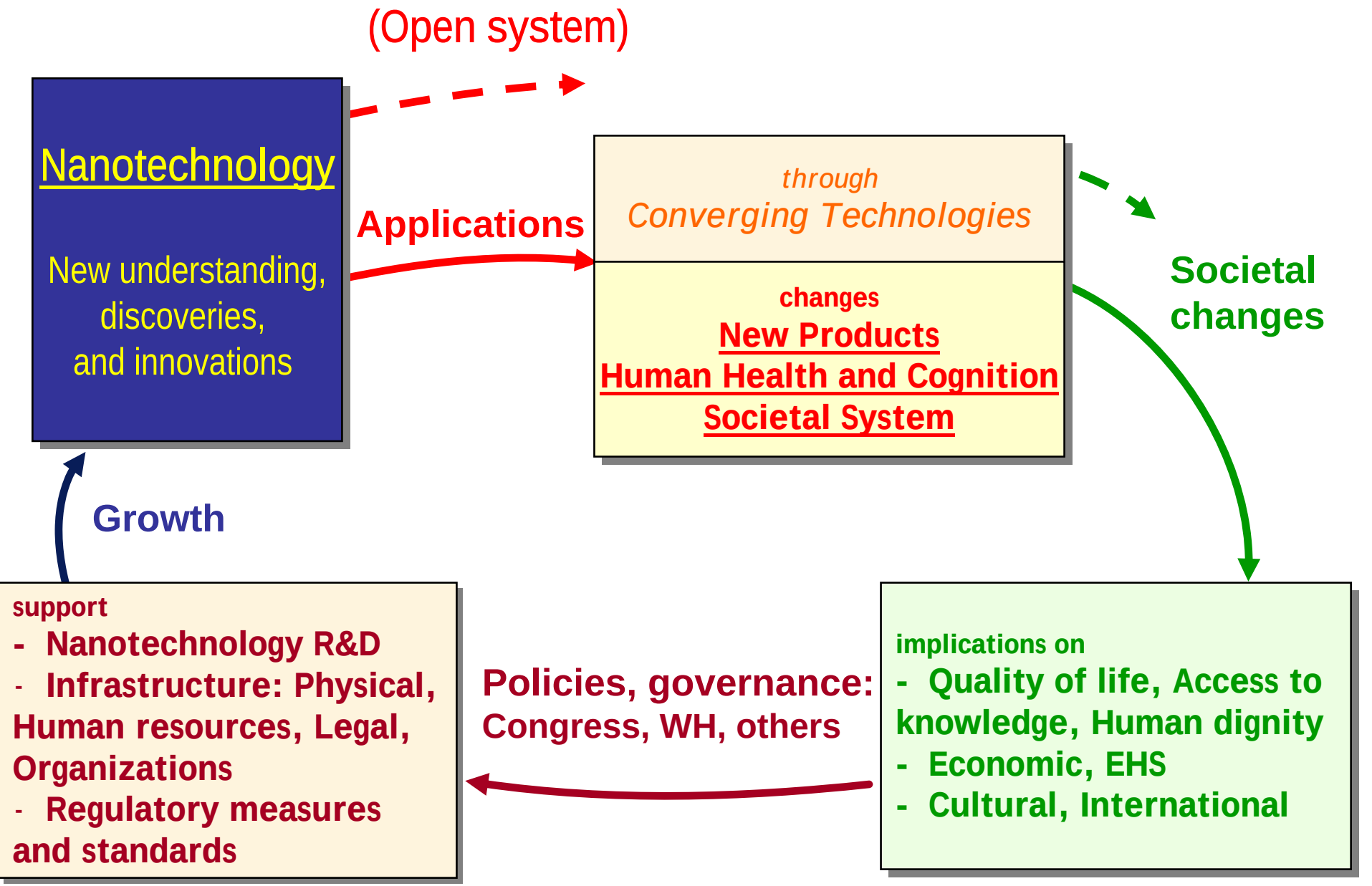
- Has stimulated R&D in all developed countries and many countries in (R&D investments in over 65 countries)
- Has stimulated the speed and scope of R&D that exceeds for now the capacity of regulators to assess human/ environmental impact

# A specific framework is needed for risk governance of nanotechnology (IRGC)

Focus on risk analysis for the higher-risk, high production applications:

- Open and complex system
  - fundamental (high risk)
  - developments are not known (role organizations)
  - accelerated (upstream measures needed)
  - cross S,E&T (complex interactions)

- With broad implications (general platform)
  - affects most areas of economic activity, effect of the “food chain” of the nanotech products (need for comprehensive evaluation of societal implications)
  - global technological implications, cross-borders (connect models for governance at the national \and the international levels, E-W, N-S)

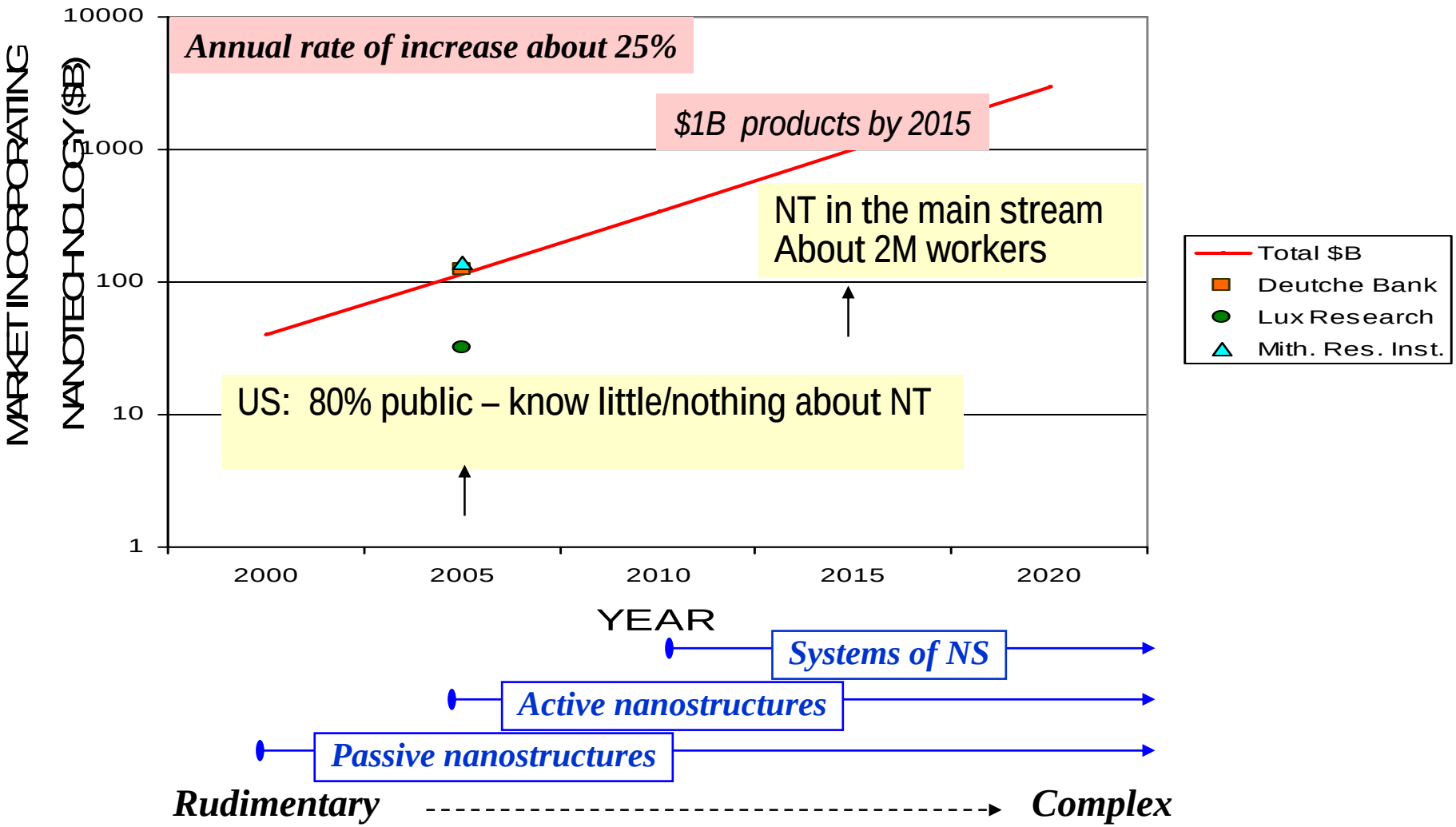



# Nanotechnology in Society

J. Nanoparticle Research, 7(2), 2005

# WORLDWIDE MARKET INCORPORATING NANOTECNOLOGY

## (Estimation made in 2000 after international study in > 20 countries)




*Reference: Roco and Bainbridge, 2001*

# Converging Technologies transforming tools (overview in 2000)
## where Nano and IT are integrators across all technology domains

*The "Push"* | *The "Pull"*

Information Technology Research

**Info**

**NBIC**

! *(system approach, .)*

**Cogno**

! *(brain-behavior, .)*

! *(neurotech, .)*

! *(cultural, .)*

**Bio**

NIH Roadmaps

NSF Biocomplexity

USDA Roadmaps

! *(biotechnology, .)*

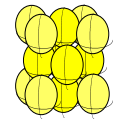
**Nano**

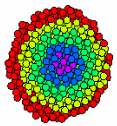
National Nanotechnology Initiative

*Reference: Roco and Bainbridge, 2003*

# TIMELINE FOR BEGINNING OF INDUSTRIAL PROTOTYPING AND NANOTECHNOLOGY COMMERCIALISATION:

## FOUR GENERATIONS OF PRODUCTS AND PRODUCTION PROCESSES





**1st: Passive nanostructures** (1st generation products)

a. *Dispersed and contact nanostructures*. Ex: aerosols, colloids

b. *Products incorporating nanostructures*. Ex: coatings; nanoparticle reinforced composites; nanostructured metals, polymers, ceramics

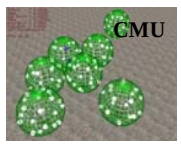
**~ 2000**

**2nd: Active nanostructures**

a. *Bio-active, health effects*. Ex: targeted drugs, biodevices

b. *Physico-chemical active*. Ex: 3D transistors, amplifiers, actuators, adaptive structures

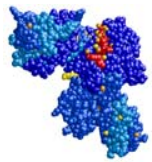
**~ 2005**




**3rd: Systems of nanosystems**

Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary

**~ 2010**



**4th: Molecular nanosystems**

Ex: molecular devices 'by design', atomic design, emerging functions

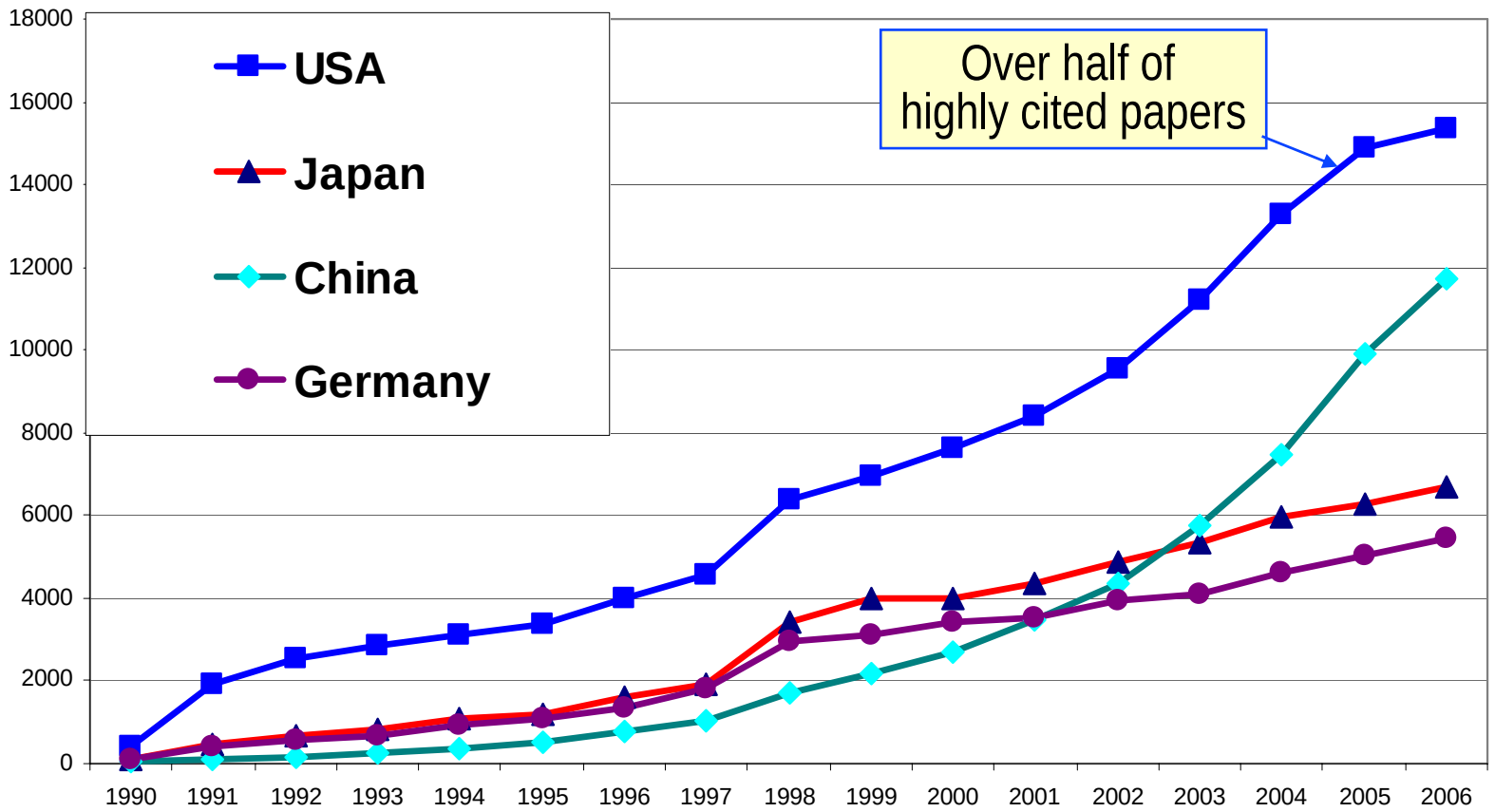
**~ 2015-2020**

Frame 1

Frame 2 — Risk Governance

*Reference: Roco, 2004*

# Nano publications per year
## 1990 - 2006

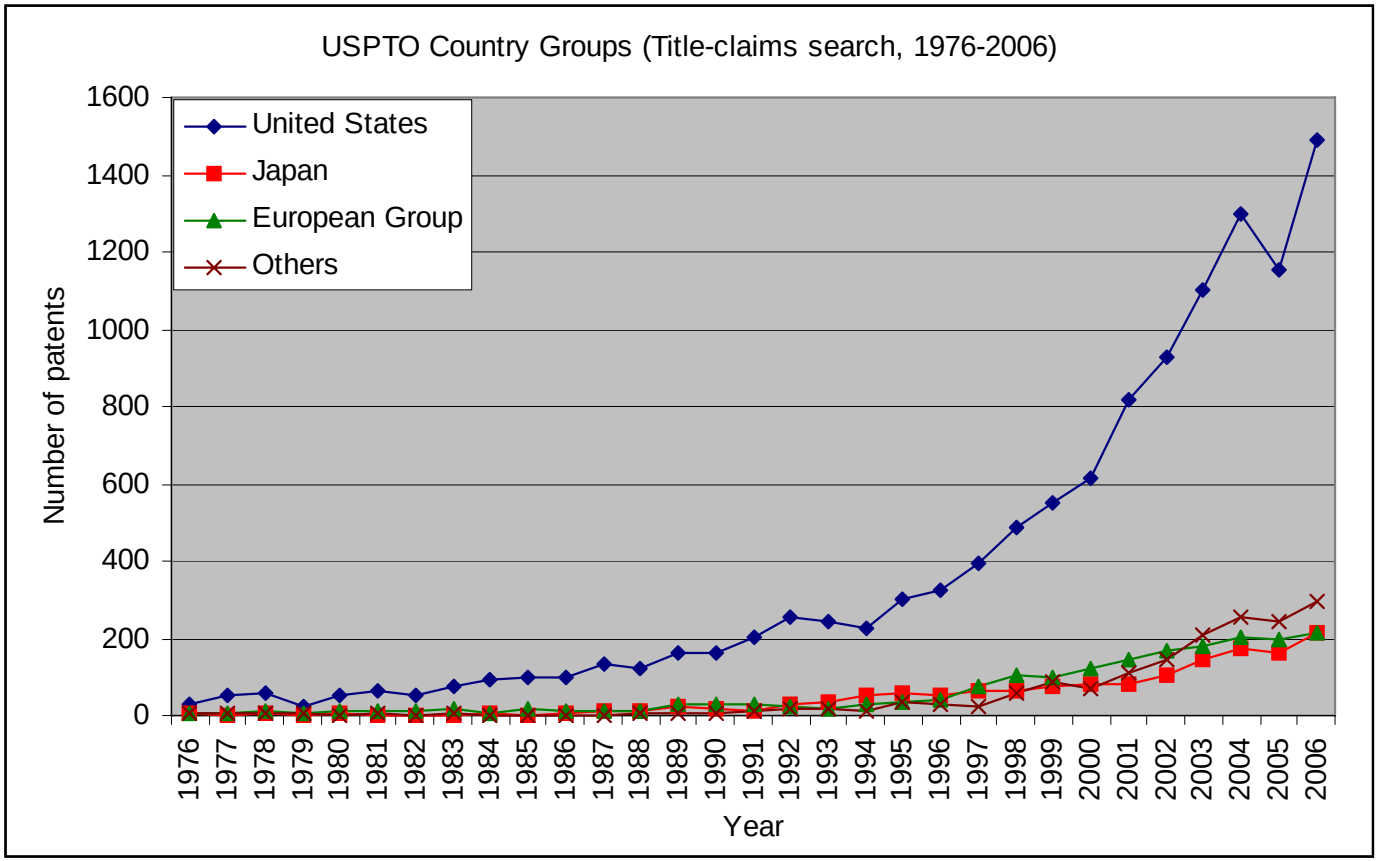



Fastest growing group in world percentage: China, Korea, Taiwan

Courtesy: Georgia Tech TPAC / CNS-ASU Analysis of SCI Publication

# NSE patents at USPTO by country group

## Assignee country group analysis by year, 1976-2006 ("title-claims" search)



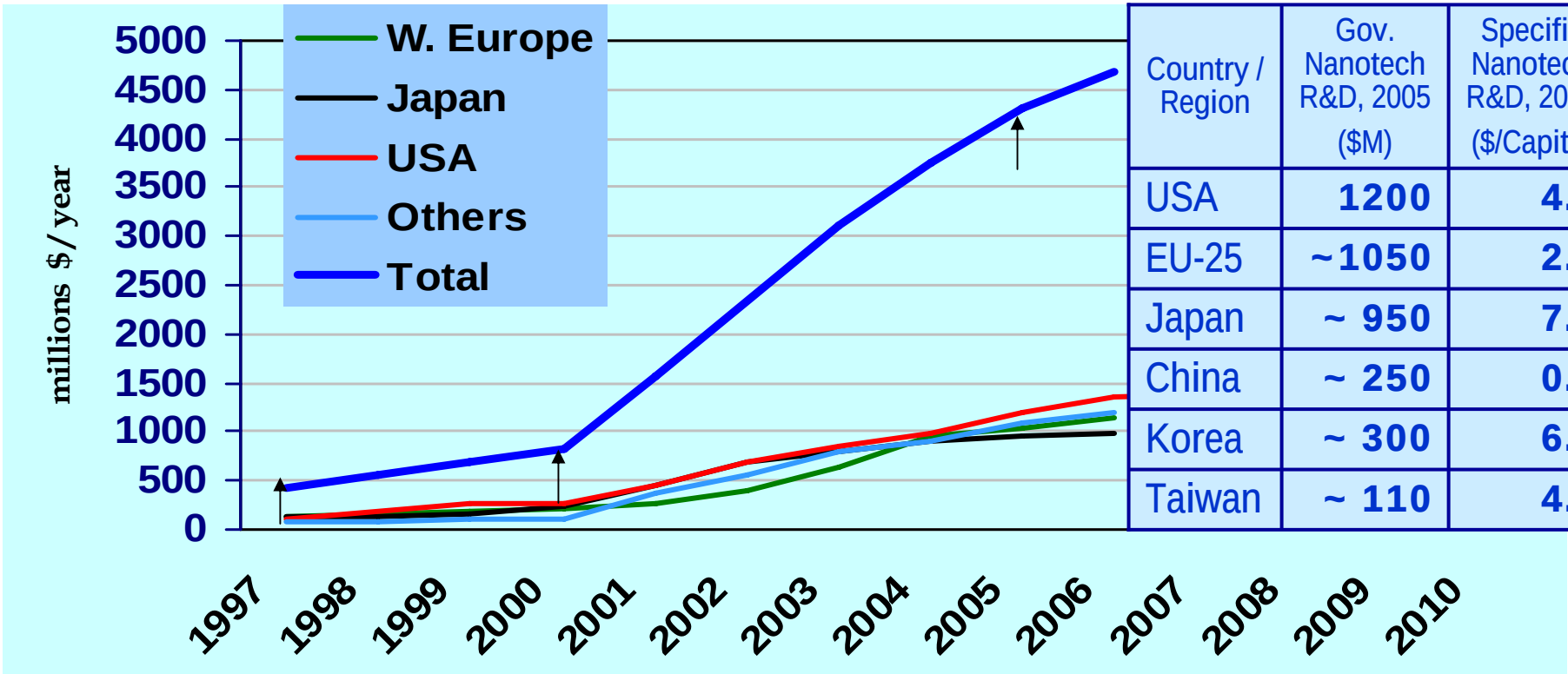

| Year | United States | Japan | European Group | Others |
|---|---|---|---|---|
| 1976 | 30 | 3 | 3 | 6 |
| 1977 | 53 | 2 | 3 | 3 |
| 1978 | 58 | 3 | 9 | 3 |
| 1979 | 26 | 2 | 7 | 3 |
| 1980 | 50 | 3 | 9 | 0 |
| 1981 | 61 | 1 | 10 | 3 |
| 1982 | 51 | 1 | 13 | 1 |
| 1983 | 73 | 1 | 15 | 4 |
| 1984 | 93 | 4 | 8 | 0 |
| 1985 | 97 | 2 | 16 | 1 |
| 1986 | 100 | 6 | 11 | 1 |
| 1987 | 132 | 12 | 11 | 0 |
| 1988 | 124 | 10 | 10 | 6 |
| 1989 | 162 | 21 | 28 | 4 |
| 1990 | 164 | 17 | 28 | 7 |
| 1991 | 204 | 14 | 28 | 9 |
| 1992 | 256 | 31 | 26 | 19 |
| 1993 | 244 | 36 | 20 | 18 |
| 1994 | 227 | 51 | 28 | 10 |
| 1995 | 302 | 57 | 33 | 36 |
| 1996 | 325 | 52 | 40 | 27 |
| 1997 | 393 | 62 | 73 | 25 |
| 1998 | 486 | 65 | 103 | 56 |
| 1999 | 548 | 75 | 96 | 85 |
| 2000 | 612 | 81 | 122 | 68 |
| 2001 | 818 | 84 | 147 | 112 |
| 2002 | 926 | 102 | 168 | 144 |
| 2003 | 1103 | 143 | 182 | 207 |
| 2004 | 1300 | 172 | 203 | 257 |
| 2005 | 1155 | 160 | 198 | 245 |
| 2006 | 1488 | 212 | 214 | 298 |
| Total | 11661 | 1485 | 1862 | 1658 |

2006 ranking : U.S., Japan, Korea, Germany, Taiwan

NSF, ASU

# Context – Nanotechnology in the World

## National government investments 1997-2006 (est. NSF)




| Country / Region | Gov. Nanotech R&D, 2005 ($M) | Specific Nanotech R&D, 2005 ($/Capita) |
|---|---|---|
| USA | 1200 | 4.0 |
| EU-25 | ~1050 | 2.3 |
| Japan | ~ 950 | 7.4 |
| China | ~ 250 | 0.2 |
| Korea | ~ 300 | 6.2 |
| Taiwan | ~ 110 | 4.7 |

Seed funding (1991 - )

NNI Preparation (vision / benchmark)

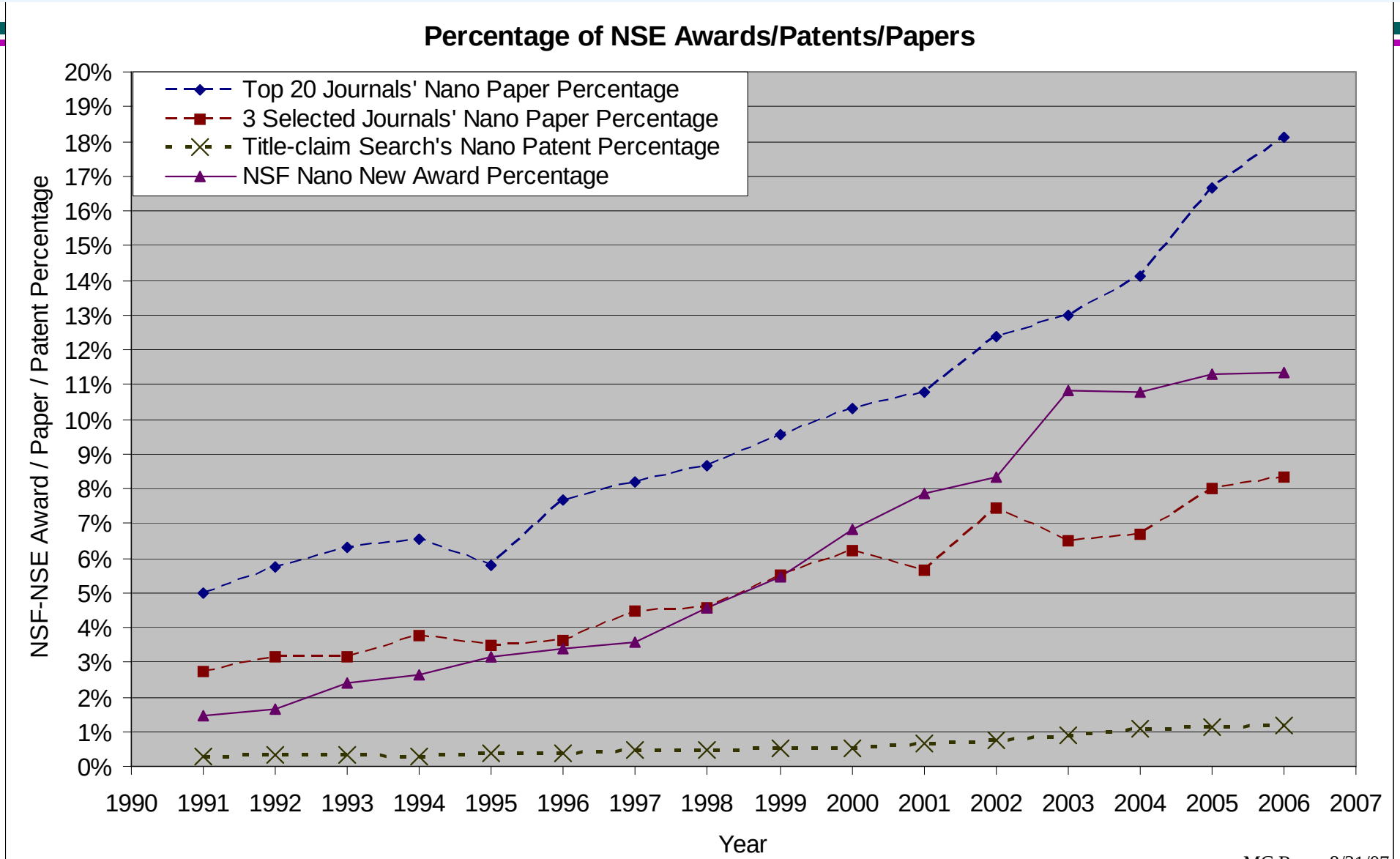
1st Strategic Plan (passive nanostructures)

2nd Strategic Plan (active ns. & systems)

Industry R&D ($6B) has exceeded national government R&D ($4.6B) in 2006

J. Nanoparticle Research, 7(6), 2005, MC. Roco

# Keyword search for nanotechnology contents: NSF awards, USPTO patents and ISO papers




MC Roco, 8/31/07

# What is Governance?

- "Governance" – a versalite term of widespread use
- Definition: Governance refers to processes, conventions and institutions that determine:
  - How power is exercised in the view of managing resources and interests;
  - How important decisions are made and conflicts resolved; and
  - How various stakeholders are accorded participation.
- General principles of "good governance" include e.g.:
  - Transparency;
  - Responsibility, accountability; and
  - Participation.
- Core principles + experience with NNI, ITR, BioCom.... ⟹ to be applied to global nanotechnology governance

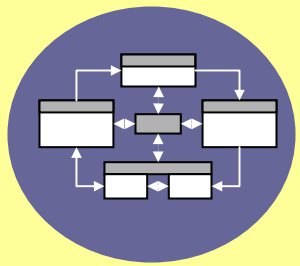
# NT Governance and Risk Governance

2000-2020

NT
GOVERNANCE

- Investment policy
- Science policy
- Risk governance
- Others

Four key functions



NANOTECHNOLOGY
RISK
GOVERNANCE (IRGC)

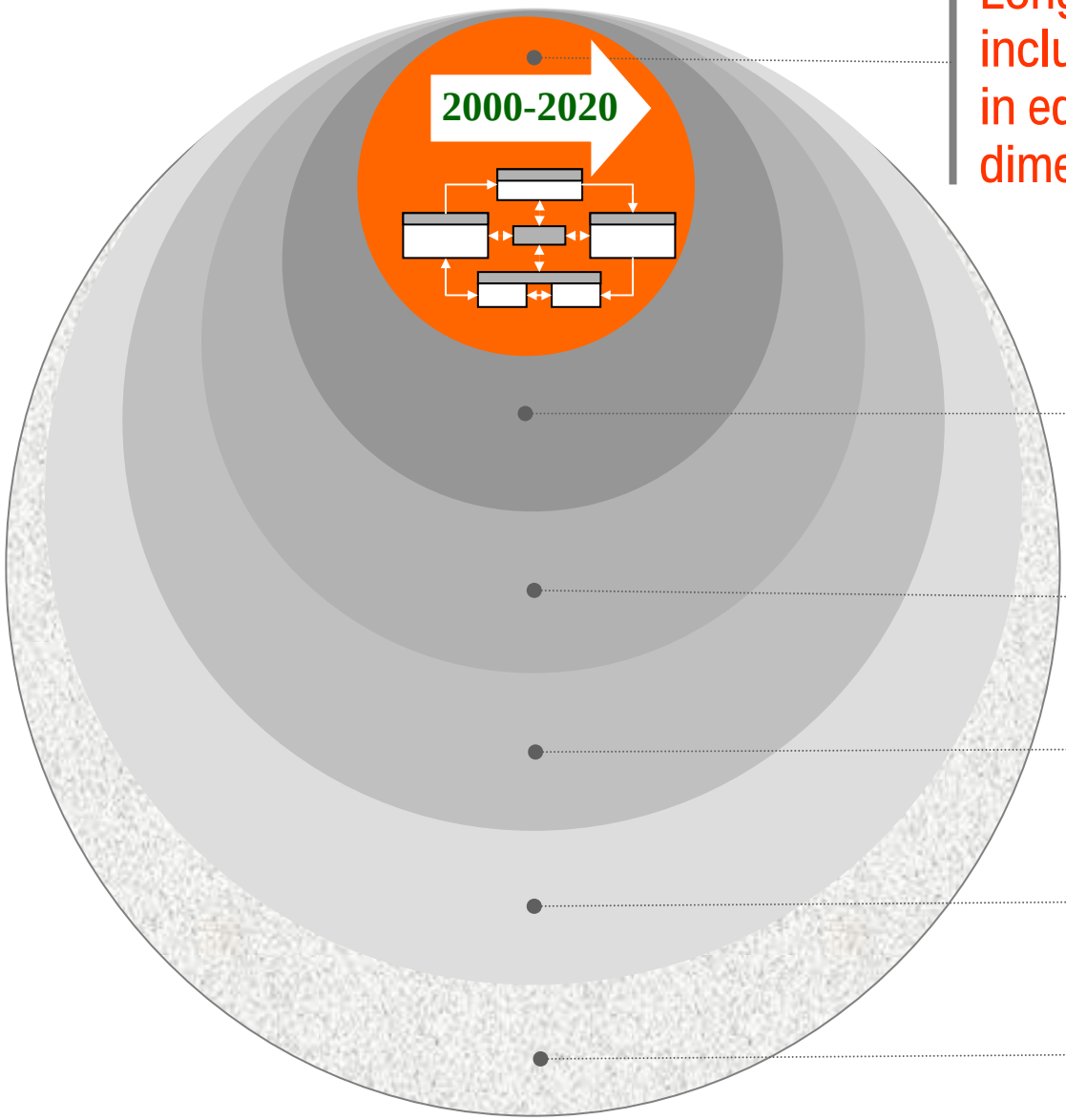
SCOPE
- Conceptual framework for integrated approach for decision-makers
- Neutral, constructive platform for all actors

GOALS
- Deficits & recommend.
- Cross stakeholders
- Multiple authorities
- Cross-boundary, global
- Short & Long-term view

WHAT IS DIFFERENT
- Structure NT development: 4 generations; 2 frames
- Include social context in assessment (ELSI + )
- Governance approach: corrective and adaptive

RISK GOVERNANCE APPROACH
- Begin with the IRGC framework
- Methodologies for 2 risk frames
- Focus: EHS, ELSI, EGI, PSI, HDI
- Stakeholder engagement
- Risk communication
- Risk governance methods

# NANOTECHNOLOGY GOVERNANCE OVERVIEW




## Core Governance Process:

Long-term view, transforming, inclusive, horizontal/vertical, priority in education, addressing societal dimensions, NT risk governance

## Main Actors:

- **R&D Organizations**
  (Academe, industry, gov.)
- **Implementation Network**
  (Regulators, business, NGOs, media, public)
- **Social Climate**
  (Perceived authority of science, civil involvement)
- **National Political Context**
- **International Interactions**

M.C. Roco, 8/31/07

# Possibilities for a Global Governance of Nanotechnology

## *General approach*

- Facilitate and provide reference models to the global self - regulating ecosystem:
  - open source models of NT development and its institutions, discovery, innovation, education, human resource, informatics
  - emerging and converging technology infrastructure;
  - use economical incentives for accelerating NT production;
  - foster suitable international organizations and agreements
- Focus on bottom-up and lateral interactions and less on top - down measures
  - using political leadership and democratic principles,
  - social consensus in knowledge based societies
- System of global communication and participation in all phases of governance, facilitated by international organizations

# *Foster suitable international organizations*

Ex: International standards organizations working on nanotechnology

**National Body International Standards Organizations**

**Treaty-Based International Standards Organizations**

**Standards Development Orgs. With Global Reach**

ASME International

# *Foster suitable international organizations*

## Ex: OECD Working Party on Nanotechnology

Working Party on Nanotechnology held its first meeting in Leuven, Belgium, on 8-9 May 2007, and decided to establish steering groups for 6 potential projects, to implement in 2007 and 2008:

A. Statistics and Measurement
B. Impacts and Business Environment
C. International Research Collaboration
D. Outreach and public engagement
E. Dialogue on Policy Strategies
F. Contribution of Nanotech to Global Challenges

# Governance of nanotechnology development: four main functions

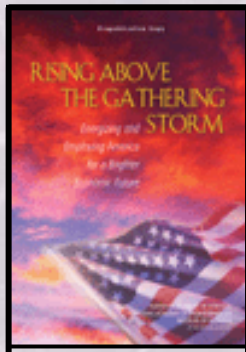
- Transformative
  investment policy, S&T policy, support innovation & informatics, prepare pipeline in education, facilitate commercialization; use NBIC integration tools
- Responsible development
  EHS, ELSI+, methods for risk governance, effective oversight, communication & participation (incl. public), voluntary measures
- Inclusive, collaborative
  Building national capacity; multi-sector partnerships; international capacity, leveraging, and research strategy
- Visionary
  Long-term and global view in planning & investment, setting priorities, human development/progress

Reference: "Governance of Converging Technologies Integrated from the Nanoscale", MC Roco, Annals New York Academy of Sciences, Vol. 1093 (2006), pp. 1-23

# The call for innovation: United States (2004-2007)

- Three reports on innovation (2004-2005):
  - "Engineering Research and America's Future: Meeting the Challenges of a Global Economy" (National Academy of Engineering)
  - "Innovate American" (Council of Competitiveness)
  - "Rising Above the Gathering Storm" (National Research Council)
- Presidential Decree:
  "American Competitiveness Initiative" (2005)

  Congressional Act:
  "US National Competitiveness Act" (2006, 2007)




*National Academies recommendations are realized in ACI.*

# Possibilities for a Global Governance of Nanotechnology

## *Transformative function*

- Support tool development, knowledge creation, innovation and informatics, and commercialization for nanotechnology, in the international context;

- Creating better opportunities for development of nanotechnology in developing countries;

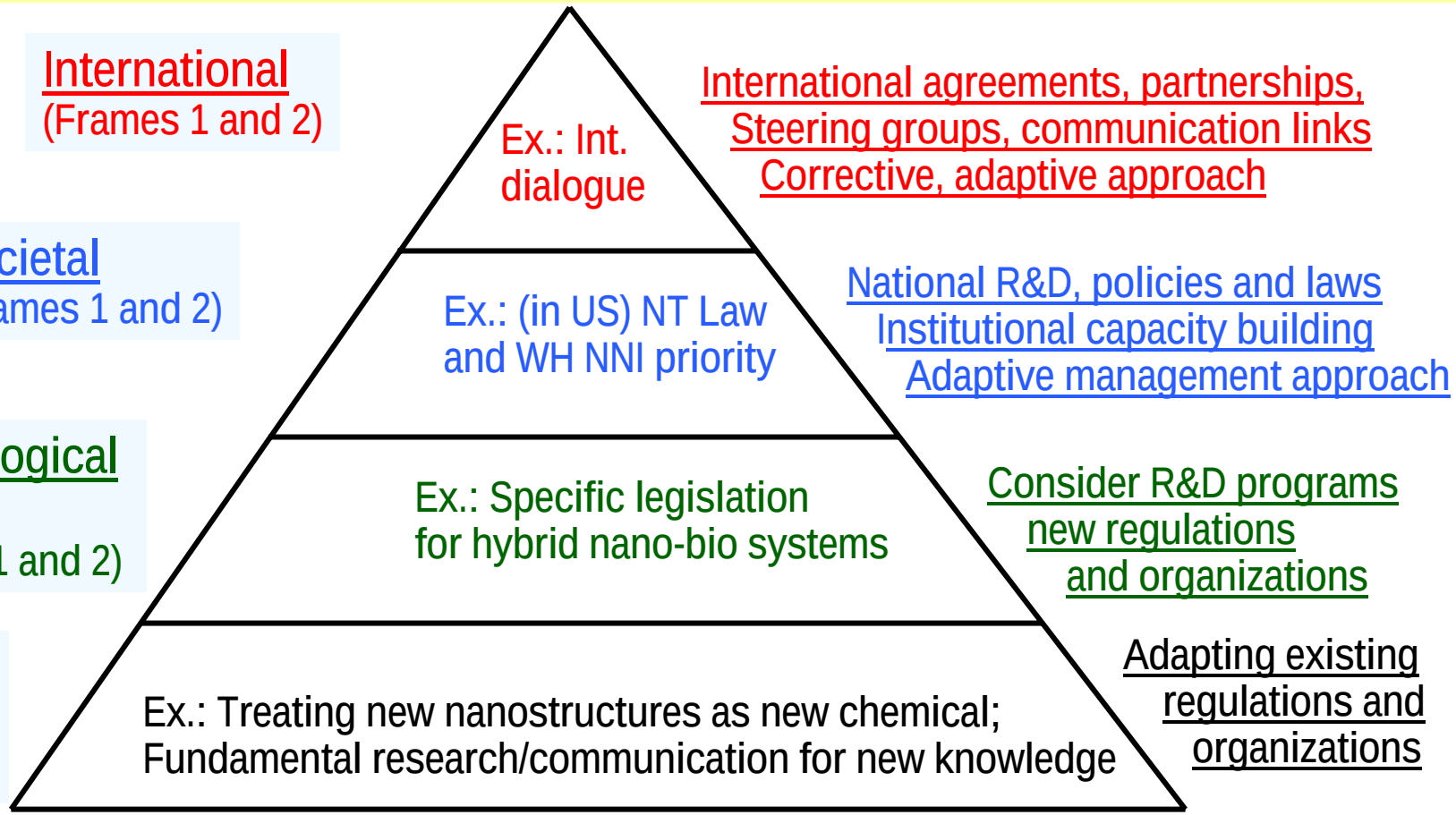
- Allocation of development funds for common topics: nomenclature, metrology, standards, patent evaluation, databases, and EHS methodologies including for a predictive toxicology approach for nanomaterials;

- Use “incentives” and “empowering stakeholders” in the open and global ecosystem

# Responsible development

# Multi-level structure of risk governance

*Implication Domain / Examples of RG activities / Implementation approach*




Reference: International Risk Governance Council, http://www.irgc.org/irgc/projects/nanotechnology/

# Possibilities for a Global Governance of Nanotechnology

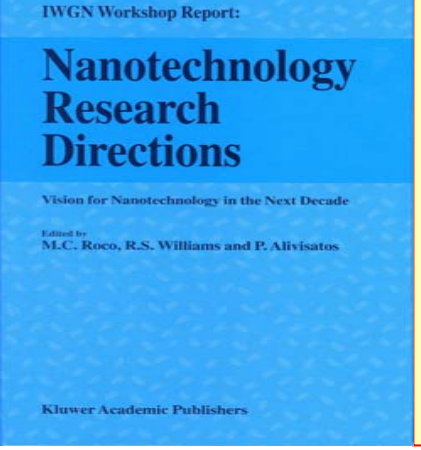
## *Responsible development function*

- Development with priority of general benefit applications such as increasing productivity and sustainable nanomanufacturing; Applying nanotechnology for improving availability of common Earth resources such as water, food, energy, and sustainable clean environment

- Voluntary measures and science-based decision for risk management

- Public inclusion and participation in international activities

- Develop organizational capacity for effective oversight




# *Inclusive*: industry, academe, government, non-government and international organizations, communication institutions, public at large.

*EX: S&T agencies participants in the National Nanotechnology Initiative*

**2001: Six Agencies**

- NIH
- NIST
- NASA
- DOD
- DOE
- NSF

**2002: Seven New Agencies**

- DOS
- DOTr
- IC
- DOT
- USDA
- EPA
- DOJ

**2003-4: Four New Agencies**

- FDA
- NRC
- DHS
- DOC TA

**2005: Six New Agencies**

- USDA FS
- DOC BIS
- USPTO
- ITC
- CPSC
- NIOSH

**2006: Three New Agencies**

- USGS
- DOL
- DOEd

# Ex.: International Dialogue on Responsible Nanotechnology R&D

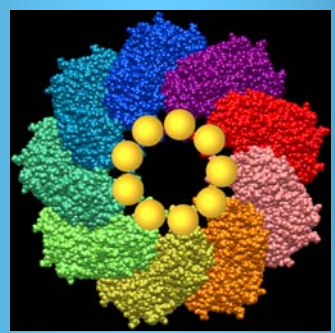
**First:** June 2004, Virginia, USA
**Second:** June 2006, Japan
**Third:** Brussels, EC

*Survey Investments*

*Current Norms*

*Recommended measures*

***International Dialogue***



***26 countries***

**Joint Statement**

**Immediate Actions**

***June 2004, Virginia***

http://www.nsf.gov/home/crssprgm/nano/dialog.htm

# Possibilities for a Global Governance of Nanotechnology

## *Inclusiveness and partnership function*

- Supporting partnerships between various stakeholders active in nanotechnology applications and related emerging technologies;

- Global communication and information, including for coordinated risk research strategies;

- Involving international organizations to advance multi stakeholder global challenges;

- Encourage international and cross-sector interactions

# Possibilities for a Global Governance of Nanotechnology

## *Commitment to long-term view*

- Detecting earlier signs of change using international expert groups; adopt real time technology assessment
- Commitment to long-term planning and priority setting using global scenarios and anticipatory measures on nanotechnology development
- Integrate nanotechnology development with other emerging and converging technologies; Conduct research specific for future generations of nanotechnology products (Frame 2, IRGC)
- Evaluate the trends for exponential growth of nanoscale knowledge and technology capabilities

# Five possibilities for global nanotechnology governance

1. *Establish models for the global self-regulating ecosystem* to enhance discovery, education, innovation, nanoinformatics and commercialization

2. *Create and leverage S&T nanotech platforms* for new products in areas of highest societal interest

3. Develop NT for *common resources and EHS requirements*

4. Support *global communication and international partnerships*

5. Commitment to *long-term, priority driven, global view* using scenarios and anticipatory measures

M.C. Roco, 8/31/07

# Responsible development context: SPECIFIC RISKS INDUCED BY EMERGING TECHNOLOGIES

- Increased technology complexity and uncertainty in comparison with traditional technologies
- Interdependency with wide ranging effects throughout our industrial and social systems, including convergence and integration trends
- Increased importance of societal implications which may not be known at the release of the technology. Importance of reducing the time delay between development of scientific knowledge and evaluation of societal implications

# Nanotechnology risk governance issues

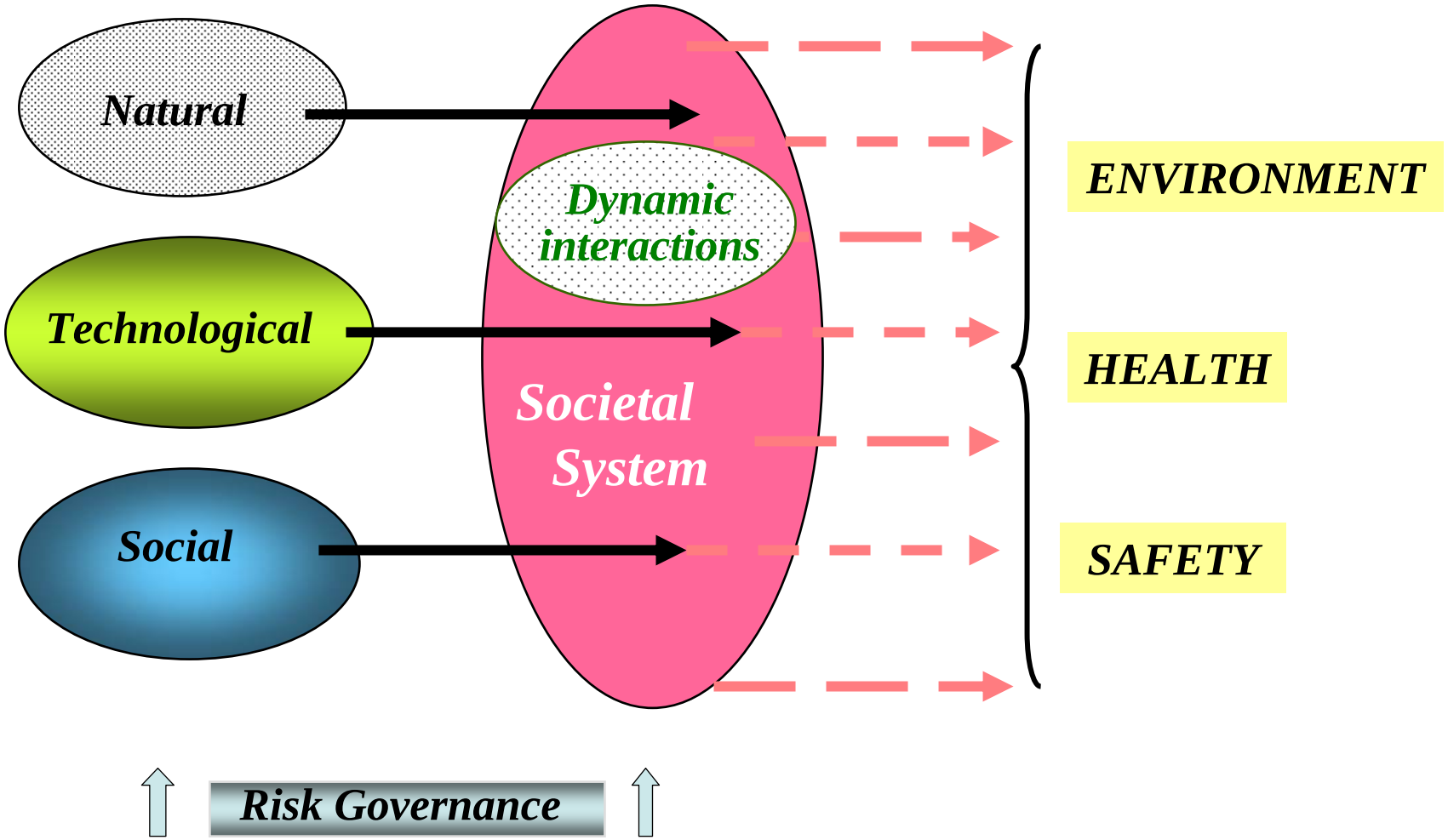
## EHS, ELSI, Education Gap, Human Development, Political and Security

- Investment policies (R&D, infrastructure) for best and equitable outcomes in society
- Occupational safety
- Consumer safety
- Environmental safety
- Legal framework (science testimony, new cases; at national and international levels) and its impact on international trade
- Individual rights to information and knowledge
- Social implications: human integrity and dignity; new opportunities and losses; societal structure; etc.)
- International relationships: IP, North-South divide, equity between haves and have-nots
- Long-term human development – need for anticipatory measures
- Need for principles to be converted to defined and planned actions

# Sources of risks and the governance approach

Various dimensions: EHS, ELSI,

Education Gap, Human Development Issues, Political and Security Issues




J. Nanoparticle Research, 2005, 7(2-3)
MC. Roco, 06/06/06

# SURVEY ON NANOTECHNOLOGY GOVERNANCE

www.irgc.org/nanotechnology (M.C. Roco and E. Litten)

- **Part A: The Role of Government**

  *Responders:* 11 countries on nanotechnology governance; and 26 countries and EU on their nanotechnology R&D programs; December 2005 (146 pages, on the web)

- **Part B. The Role of Industry**

  *Responders:* Industrial Technology Research Institute (Chinese Taipei), Allianz and NanoBioNet (Germany), Ayanda Biosystems and Swiss Re (Switzerland), Chair of the International Organization for Standardization Technical Committee 229 on Nanotechnologies (UK), Canon, Environ, Intel, NanoDynamics Inc. and Pfizer (US)

- **Part C. The Role of Risk Research Organizations**

  *Responders:* Ochanomizu University (Japan), Institute for Occupational Health Sciences (IST) (Switzerland), Centre for Nanotechnology in Society (University of California, US); Center for Science Technology and Public Policy (University of Minnesota, US); Woodrow Wilson International Center for Scholars (US)

- **Part D. The Role of NGOs**

  *Responders*: ETC Group (Canada), Demos, The Forum for the Future, Greenpeace (UK), the Center for Responsible Nanotechnology, Environmental Defence, Foresight Nanotech Institute, the National Resources Defence Council and Sciencecorps (US).

# IRGC Survey on Nanotechnology Governance

## Areas of relevance in governance (December 2005)

| Stakeholder | EHS | ELSI | Education Gap | Political and Security | Human Develop. |
|---|---|---|---|---|---|
| A. Government | 2 | 1 | - | - | - |
| B. Industry | 2 | - | 1 | - | - |
| C. R&D risk organizations | 2 | 1 | - | - | - |
| D. NGOs | 2 | 1+ | - | - | - |
| **Summary:** | **8** | **3** | **1** | **0** | **0** |

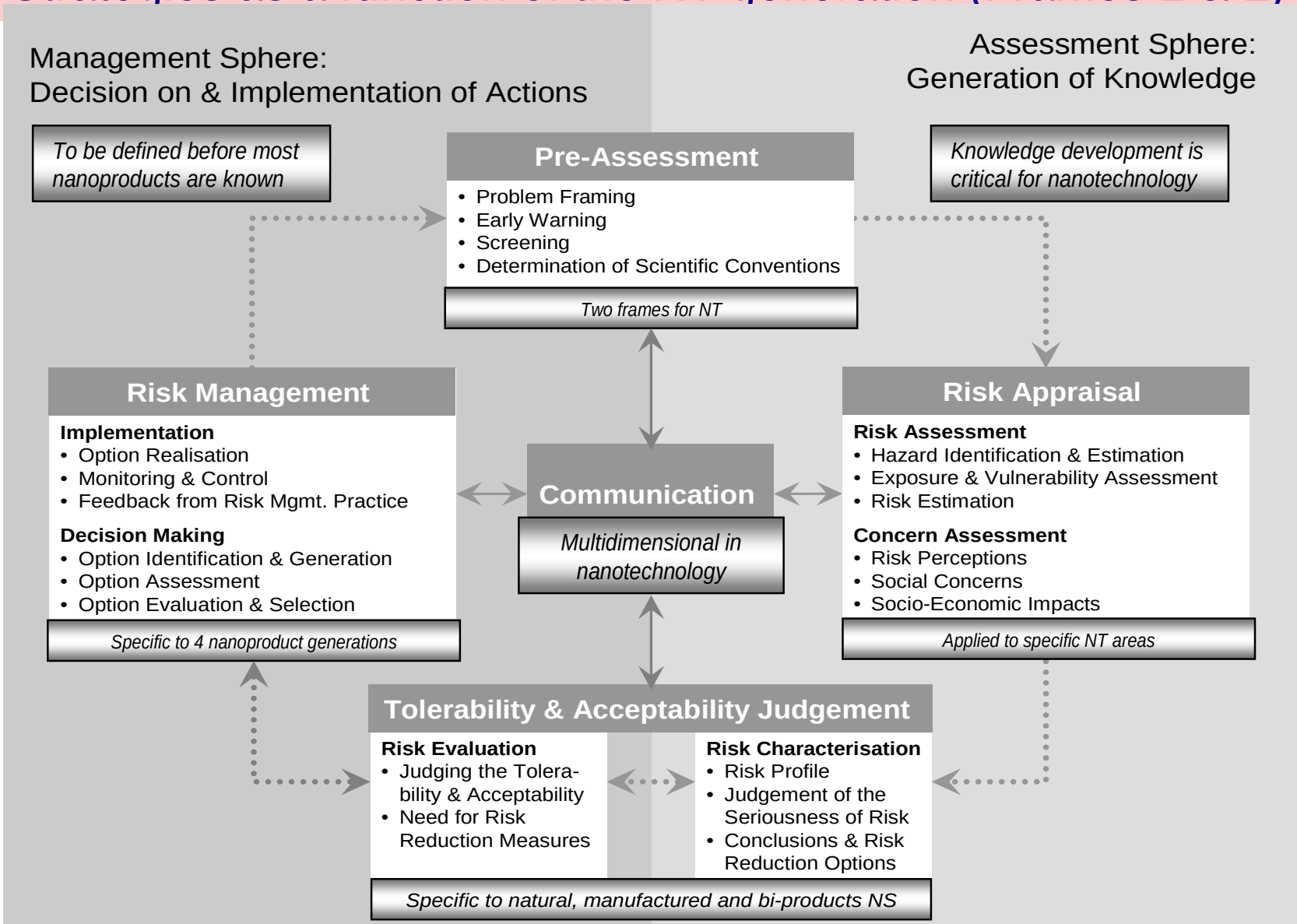
# Characteristics of a risk governance framework (IRGC Nanotechnology Policy Paper, 2007)

- *Adaptive*, valuing flexibility in the application of risk management strategies as knowledge and understanding of the field develops
- *Collaborative*, sharing information, skills and expertise internationally among different agencies and stakeholders
- *Global*, proposing international minimal “level playing field” guidelines and reference models to generate confidence in safety management in a globalized economy
- *Realistic and Fast*, recognizing that such a dynamic field calls for active and ongoing learning, rather than an “after the fact” approach, including building on emerging experience of those new technologies
- *Responsive to essential human values*, such as equity, respect of ethics, safety, equal opportunities and right to privacy

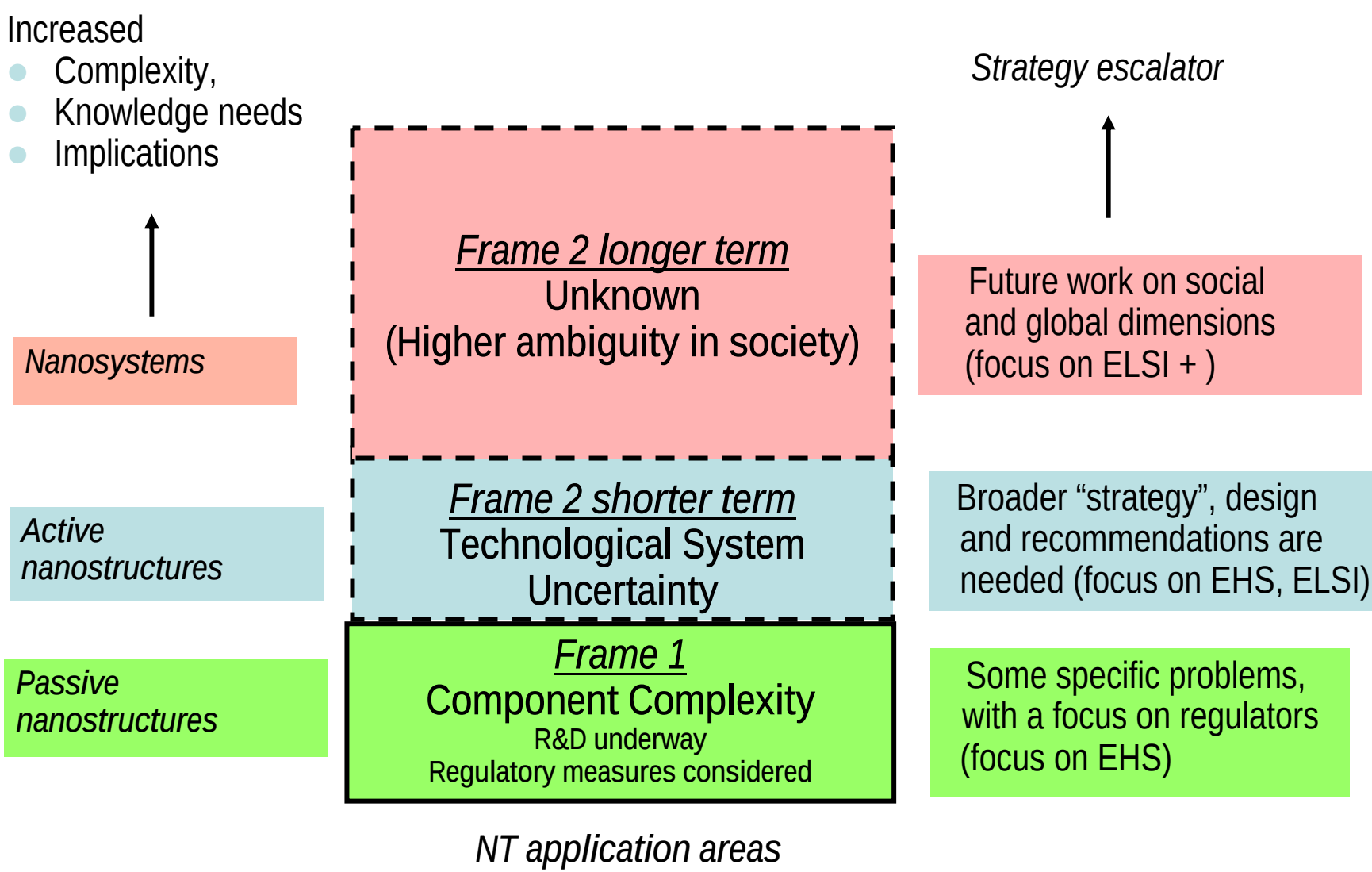
# Include IRGC approach to the governance of risks

- Adds a pre-assessment phase that includes ‘problem framing’, ‘early warning’, and ‘organisation of the risk governance process’;
- Considers the assessment of societal concerns alongside conventional risk assessment (in order to allow the scientific consideration of stakeholder and public concerns by risk managers in the process of generating the knowledge required for risk evaluation and management);
- Provides for a risk evaluation and management process that includes the concerns, interests and values of stakeholders through different participative procedures; and
- Considers risk communication as an integral part of all stages of the risk governance process and vital for effectively linking the different components.

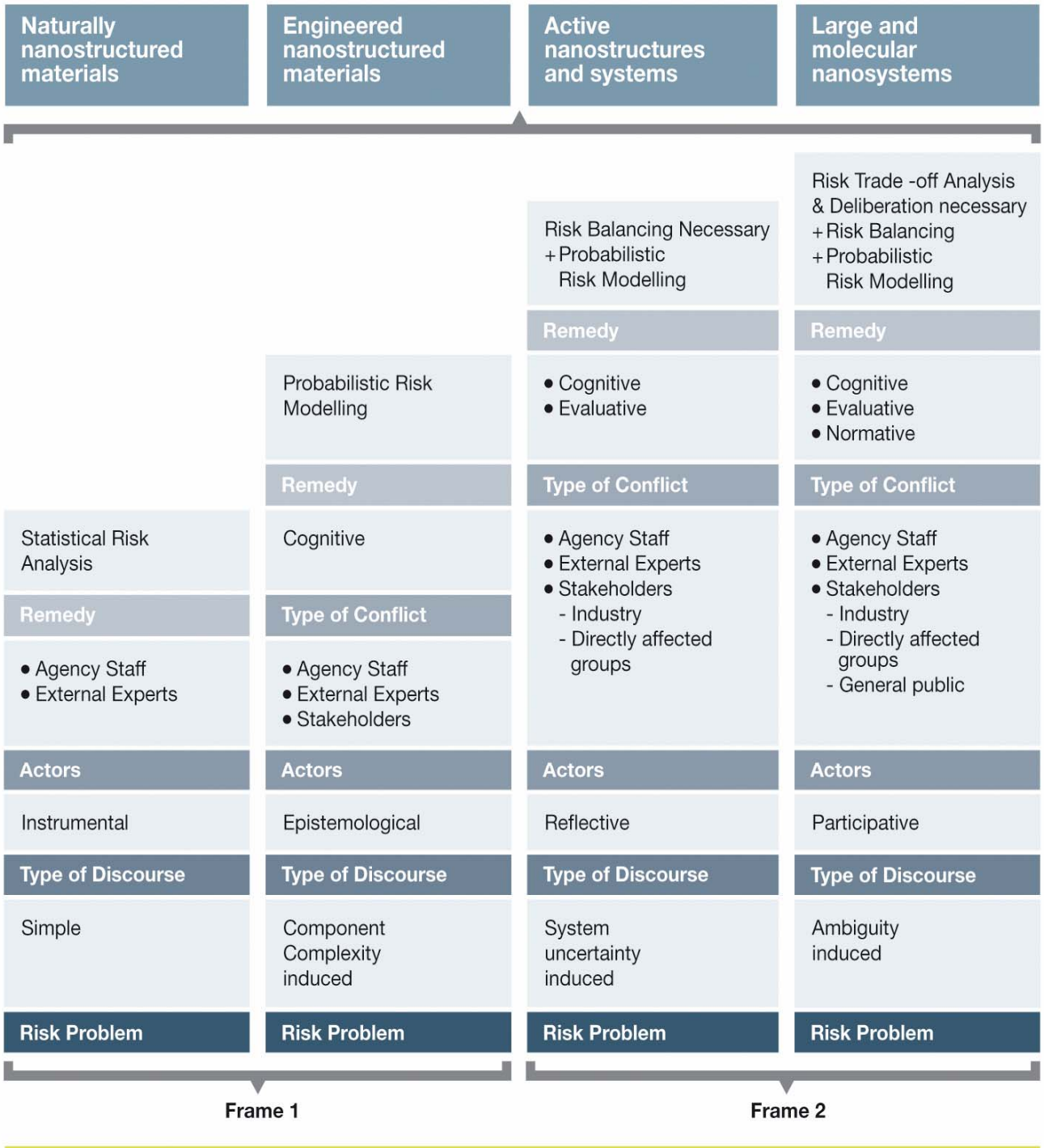
# IRGC RISK GOVERNANCE FRAMEWORK FOR NT: Strategies as a function of the NT generation (Frames 1 & 2)



# Strategies as a function of the generation of nanotechnology: Application to Frame 1 and Frame 2 (pre-assessment)




J. Nanoparticle Research, 2006, Vol. 8(2)




# The Risk Management Escalator and Stakeholder Involvement

(from Simple via Complex and Uncertain to Ambiguous Phenomena) with reference to nanotechnology

# Risk governance of nanotechnology: priority actions by stakeholders (1)

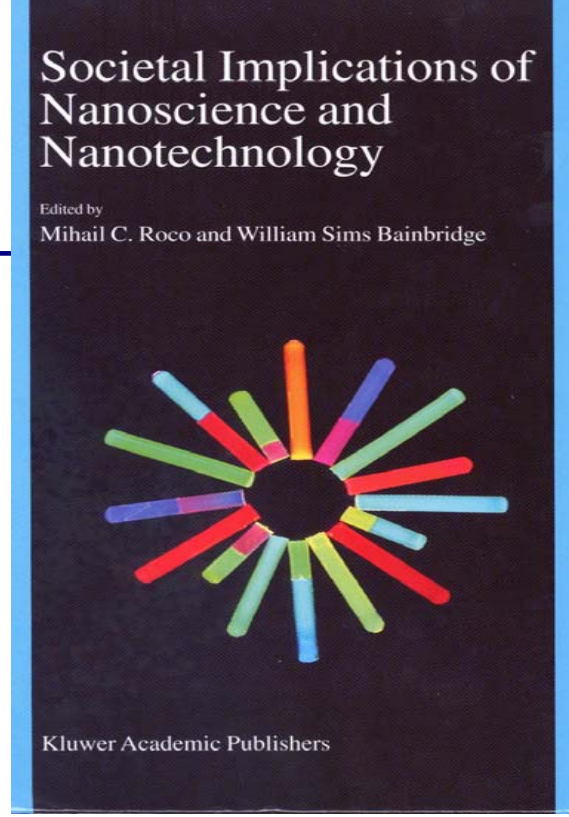
- Agree global nomenclature and standard approach to characterisation of nano realm
- Establish occupational and consumer safety guidelines based on particle and other material behaviour at the nanoscale
- Communication and information: between stakeholders to facilitate governance at regional/ national/ international levels
- Voluntary systems: Initial collection and organisation of data from industry to establish good practice guidelines. Initial activities to advance voluntary systems in the U.K. and U.S. have already begun in 2006

*Reference: Roco and Renn, IRGC, 2006 and 2007*

# Risk governance of nanotechnology: priority actions by stakeholders (2)

- Review applicability of existing regulation in analogous fields to speed up implementation
- Investment in risk related research for developing a metrology for characterising and sensing nanostructures and a predictive toxicology approach
- Research for Frame Two including development of scenarios, infrastructure models and systems for earlier detection of major changes
- Assessment and extension of existing and new models for public involvement

# Societal Implications: Follow-up of the September 2000 report




- Make support for social, ethical, and economic research studies a priority:
  **(a) New theme in the NSF program solicitations;**
  **(b) Centers with societal implications programs;**
  **(c) Initiative on the impact of technology, NBIC, HSD**
- NNCO – communicate with the public and address Environmental, Health and and Safety issues, and unexpected consequences

http://nano.gov

- NSET's Nanostructures Environmental and Health Issues working group has been established in 8/2003, 12 agencies
- Workshop with EC (2001); Links to Europe, Americas, Asia; International Dialogue (26 countries, NSF-sponsored)

# Key issues in long term (2000 - )

- Respect human right to: access to knowledge and welfare; human integrity, dignity, health and safety
- Balanced and equitable R&D nanotechnology investment
- Environment protection and improvement (water, air, soil) Sustainable development, life-cycle of products, global effects (weather), eliminate pollution at the source
- Economic, legal, ethical, moral, regulatory, social and international (developed-developing countries) aspects Interacting with the public and organizations
- Adaptive/corrective approach for a complex system

***Immediate and continuing issues:***

- *EHS in research laboratories and industrial units*
- *Harmonizing nomenclatures, norms and standards*
- *Primary data and methodology for risk analysis*

# NNI activities
## for Environmental, Health and other Societal Implications

*A. Align R&D investment with societal implications*

*B. Evaluate and implement regulatory standards*

*C. Coordinated measures for EHS and ELES*

*D. Periodical meeting for grantees, setting research targets, and interaction with industry and the public*

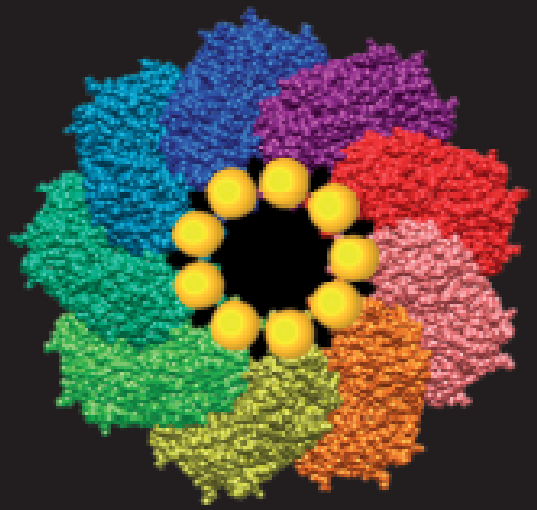
*E. International collaboration (International Dialog for Responsible R&D of Nanotechnology)*

*Reference: Roco, Environmental S&T, 2005*

# Nanotechnology: Societal Implications I

## Maximizing Benefits for Humanity

Edited by
Mihail C. Roco and William Sims Bainbridge



Springer

**November 2006**

# Progress in Convergence

## *Technologies for Human Wellbeing*

EDITORS
William Sims Bainbridge
Mihail C. Roco

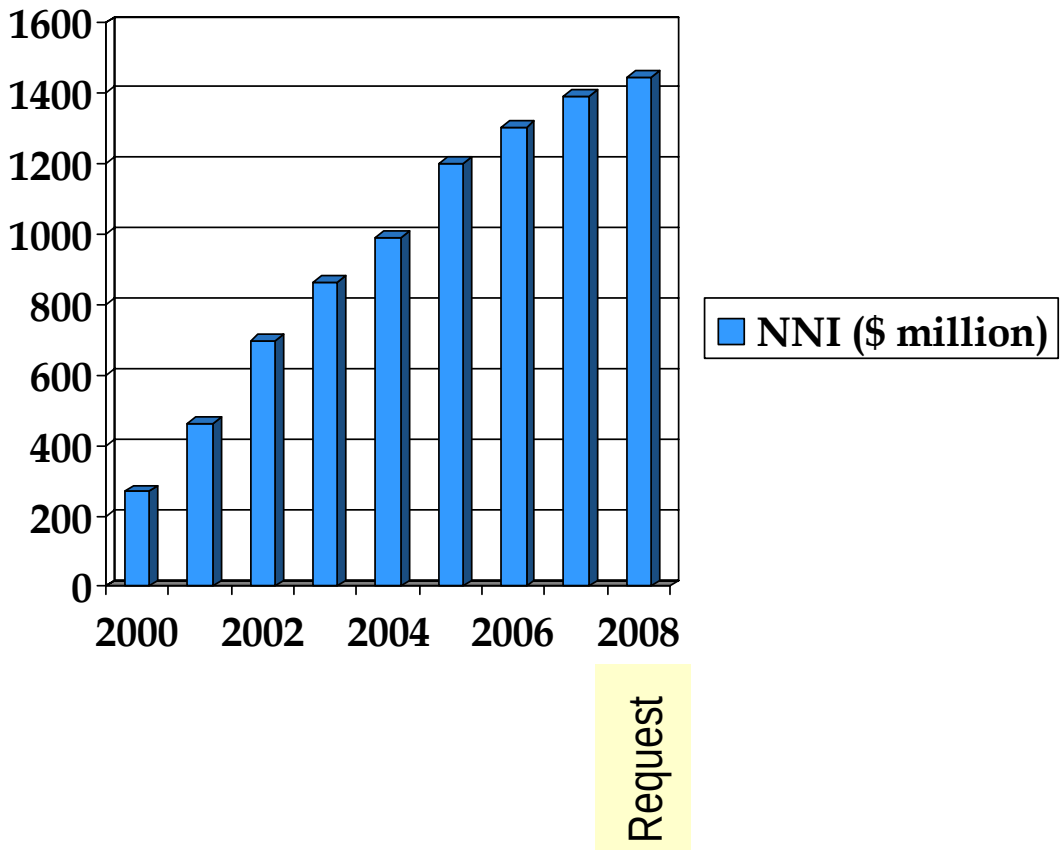
**NYAS** **December 2006**

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES VOLUME 1093

# FY 2008 U.S. National Nanotechnology Initiative Budget Request - $1,445 million

Average rate of increase since 2000: over 30% per year
using bottom-up project based approach

| Fiscal Year | NNI |
|---|---|
| 2000 | $270M |
| 2001 | $464M |
| 2002 | $697M |
| 2003 | $862M |
| 2004 | $989M |
| *2005 | $1,200M |
| *2006 | $1,303M |
| 2007 | $1,392M |
| R 2008 | $1,445M |




* Includes Congressionally directed additional funding

February 5, 2007

# NSET established NEHI Working Group in Oct. 2003
## - *PURPOSE* -

- Exchange of information among agencies
- Facilitate the identification, prioritization, and implementation of research and other activities
- Promote communication of information related to research on environmental and health implications of nanotechnology

*NEHI = "Nanomaterials Environmental and Health Implications"*

# Recent NEHI activities

www.nano.gov

- "EHS Research Needs for Engineered Nanoscale Materials" (September 2006)
- "Prioritization of EHS Research Needs for Engineered Nanoscale Materials" (August 2007, released for public comment)
- Current NNI EHS research portfolio (est. Fall 2007)
- Gaps analysis and strategy to address EHS research priorities and opportunities for interagency collaboration (est. Fall 2007)
- Process for periodic review of progress and research priorities

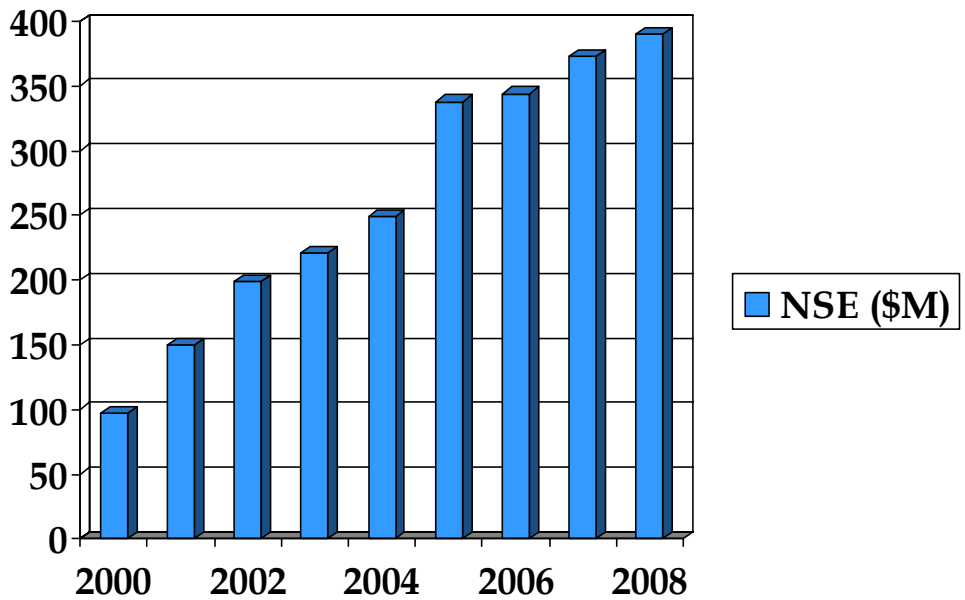
# NSF – discovery, innovation and education in Nanoscale Science and Engineering (NSE)

www.nsf.gov/nano , www.nano.gov

FY 2008 Request: $390M ~1/4 of Federal and ~1/12 of World Investment

- Fundamental research - seven PCAs with new priorities
- Establishing the infrastructure - over 3,000 active projects; 24 large centers, 2 user facilities (NNIN, NCN), multidisciplinary teams
- Training and education – over 10,000 students and teachers/yr

| Fiscal Year | NSF |
|---|---|
| 2000 | $97M |
| 2001 | $150M |
| 2002 | $199M |
| 2003 | $221M |
| 2004 | $254M |
| 2005 | $338M |
| 2006 | $344M |
| 2007 | $373M |
| **R 2008** | **$390M** |



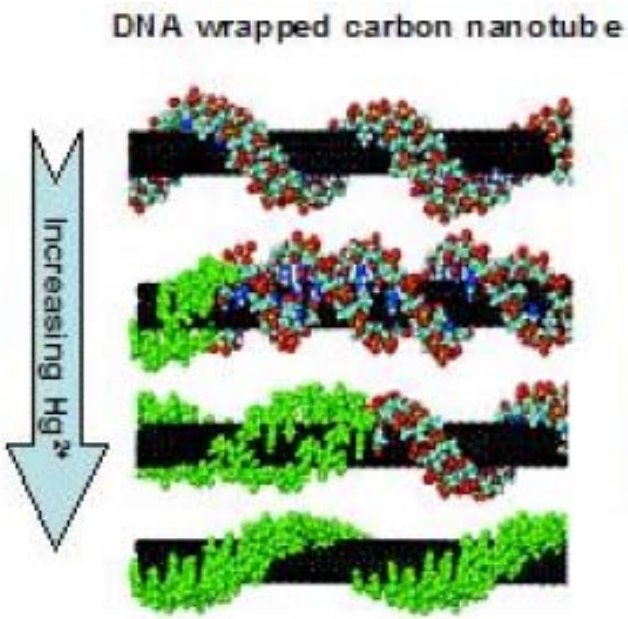
# NSF Overview on nano ENV (1)

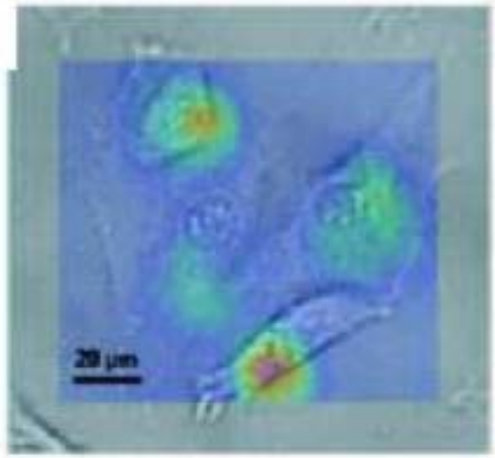
- "Upstream" research and education since 2000;
  - 2000 – nanoparticles and other passive nanostructures
  - 2003 – nanomanufacturing safety; NISE, NCLT, NSEC
  - 2006 – added focus on the 2nd-3rd generations
  - 2010 – to focus on nanosystems (more complex, dynamic)

- Main topics funded in 2006 in the EHS NNI cross-cut

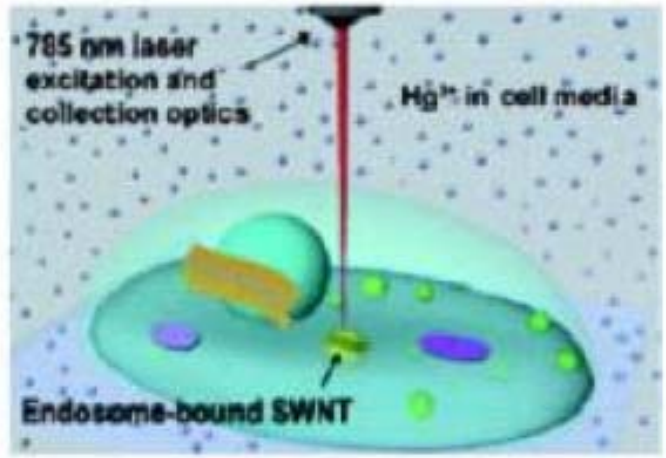
  (a) instrumentation, metrology, and analytical methods;
  (b) effects on biological systems and human health;
  (c) effects on the environment;
  (d) monitoring methods for health / env. surveillance; and
  (e) risk assessment and management methods.

# Fluorexcent Nanotube Sensors for Measuring Toxic Chemicals Inside of Living Cells




N-IR fluorescence maps concentration




Schematic of sensor localization

**A biomolecular transformation of DNA on a carbon nanotube detects toxic mercury via infrared fluorescence from inside of living mammalian cells**

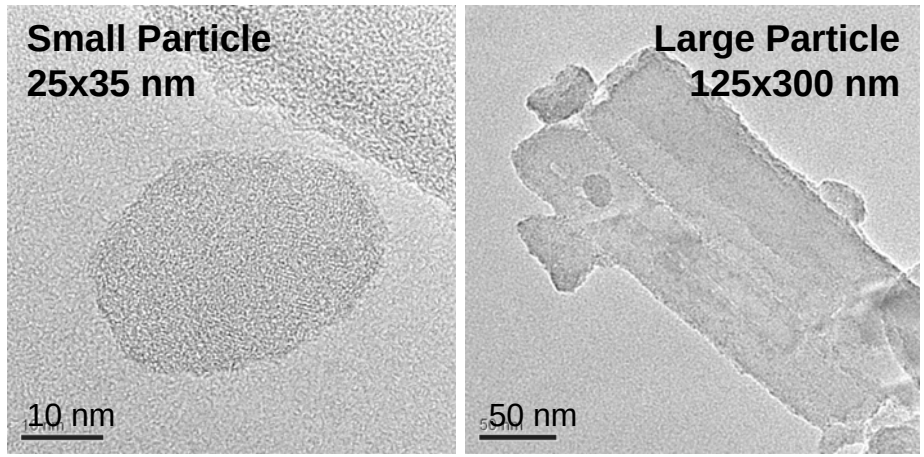
**M. Strano, UIUC**

# SIZE is EVERYTHING

## Fate and Impacts of Manufactured Carbonaceous Nanomaterials in the Environment

**Size and "stickiness" determine fate in air, water, and soil.**

| Preparation | Resulting size distribution |
|---|---|
| Stirring in organic solvent | Single peak at 200 nm |
| Stirring in pure water | Small peak at 30 nm, large peak at 100 nm |
| Stirring in water with citrate | Primary particles of 10 nm, aggregated |
| Aerosolized fr om pure water | Single peak at 40 nm |




**Aging of airborne nanoparticles by ozone affects their stickiness to soil in water**

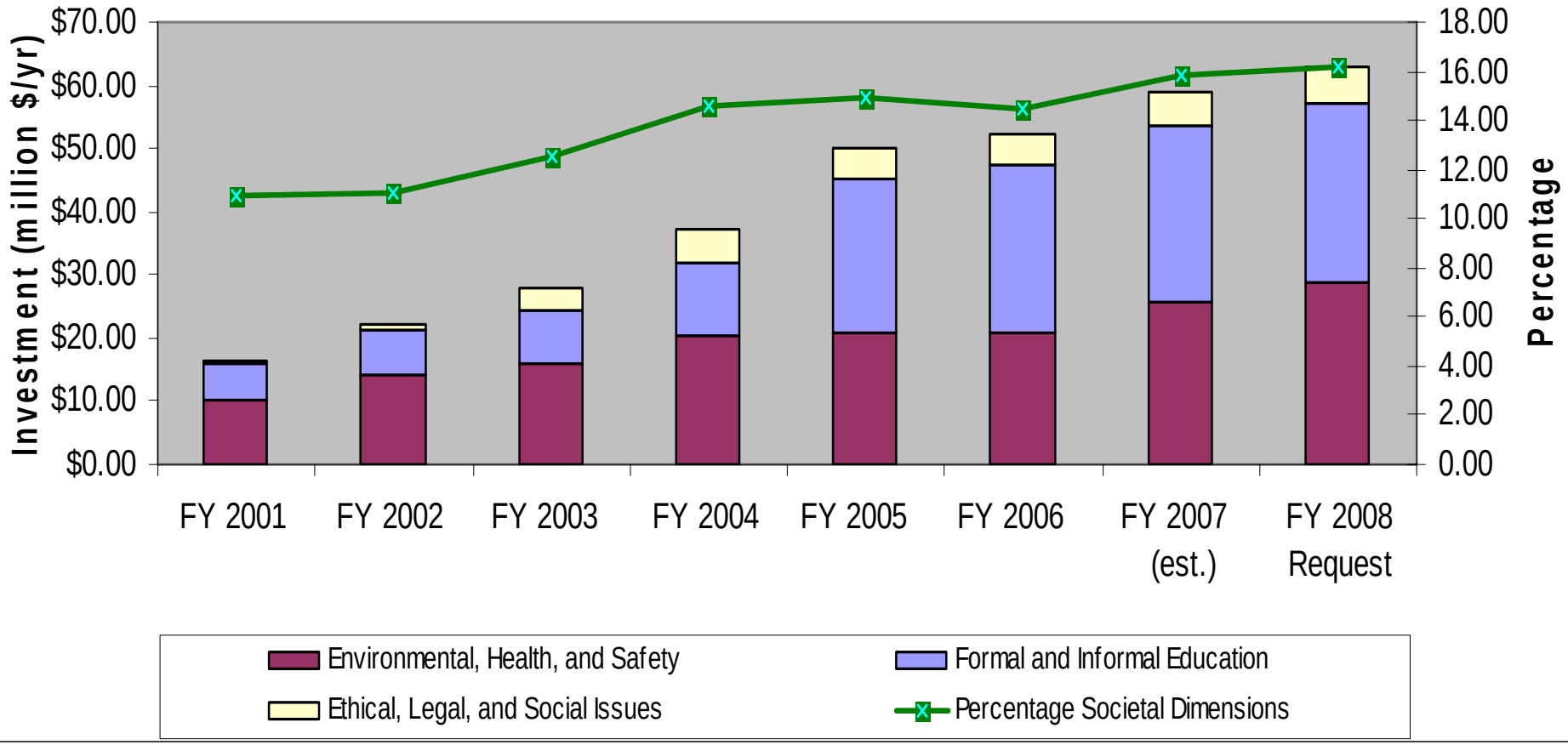
*Linsey C. Marr, Peter J. Vikesland, Harry C. Dorn, Virginia Tech*

# NSF Overview on nano ENV (2)

- Societal Dimensions in FYs 2007 estimate & 2008 request:
  - 2007: $59.0 million (69%) of all NNI - $85.9 million
  - 2008: $62.9 million (65%) of all NNI - $97.5 million
- EHS: NSF dedicates about 7% of its NNI budget for projects with a primary focus on fundamental aspects of environmental implications and applications of nanomaterials:
  - 2007: $25.7 million (6.9%) of the total NSF/NNI estimate
  - 2008: $28.8 million (7.4%) of the total NSF/NNI request
- These topics are supported through all NSF programs

# NSF Investment in Societal Dimensions of NT

Of FY 2008 NNI/NSF request of $390 M, $63 M or 16.1% is for SI, and $28.8 M (7.4%) for nano EHS



# Closing remarks

- **Seeds for global nanotechnology governance including risk governance have been created**, and there are opportunities for a systemic approach in several areas - such as for innovation, nanoinformatics, standards and EHS knowledge development

  Needs in global governance:
  - coordinated policies and investments where cultural and ideological / economical differences are important;
  - nanotechnology applications for sustainable Earth resources

  Needs in global risk governance:
  - coordinated research, methodologies and oversight mechanisms;
  - addressing future generations of nanoproducts

- **Increased global interactions are needed** for immediate risk governance implementation and longer-term research goals

# Several Background References

- "Societal Implications of Nanoscience and Nanotechnology", Kluwer, now Springer (Roco and Bainbridge, 2001)
- "Coherence and Divergence of Megatrends in S&E" , Proc. Swiss Academies, 2000; and J. Nanoparticle Research, Vol. 4 (Roco, 2002)
- "Nanotechnology–Unifying and transforming tools", AIChE J. (Roco, 2004)
- "Environmentally Responsible Development of Nanotechnology", Environmental Science and Technology (Roco, 2005)
- "Nanotechnology's Future", Scientific American, August 2006, (Roco, 2006)
- "Nanotechnology: Societal Implications - Maximizing Benefits for Humanity", 2 vols., Springer (Roco and Bainbridge, 2005)
- "The NNI: Past, Present and Future", in Handbook on Nanoscience, Engineering and Technology, CRC, Taylor and Francis, (Roco, 2007)
- "Nanotechnology Risk Governance" (Roco and Renn, 2007), in book Global Risk Governance: Applying and Testing the IRGC Framework, Renn and Walker (eds.), Springer
- "Possibilities for Global Governance of Converging Technologies", J. Nanoparticle Res. (Roco, 2007)